



# **Human Decision-Making Under Uncertainty in the Upstream Oil and Gas Industry**

**Steve Mackie**

**BSc – Macquarie University**

**MBA – University of South Australia**

This thesis is submitted in fulfilment of the requirements for the degree of Doctor of Philosophy at the Australian School of Petroleum, Faculty of Engineering, Computer and Mathematical Sciences, The University of Adelaide

July 2007

---



## Table of Contents

<b>Abstract</b>	<b>vii</b>
<b>Declaration</b>	<b>viii</b>
<b>Acknowledgements</b>	<b>ix</b>
<b>Papers and Presentations</b>	<b>xi</b>
<b>Chapter 1: Introduction</b>	<b>1</b>
1.1 Background to Thesis	2
1.2 Outline of Thesis	6
<b>Chapter 2: Normative and Behavioural Decision-Making in the Upstream Oil and Gas Industry</b>	<b>11</b>
2.1 Introduction	12
2.2 Theoretical Background	12
2.2.1 Normative Decision Making	13
2.2.2 Behavioural (or Descriptive) Decision-Making	17
2.2.3 Decision Type	26
2.3 Application in the Upstream Oil and Gas Industry	30
2.3.1 Normative Decision Making	30
2.3.2 Behavioural (or Descriptive) Decision-Making	35
2.3.3 Decision Type	38
2.4 Summary	40
2.4.1 Normative Decision Making	40
2.4.2 Behavioural (or Descriptive) Decision-Making	41
2.4.3 Decision Type	42
2.5 Research Questions	43
<b>Chapter 3: The Theory of How Decisions Should Be Made</b>	<b>47</b>
3.1 Aim	48
3.2 Individual Decision-Making	48
3.2.1 Decision-Making Processes	51
3.2.2 Decision-Making Under Uncertainty as a Probabilistic Process	59
3.2.3 Implementation	60
3.3 Decision Outcome	61
3.4 Decision-Making Tools	63
3.5 Team Decision-Making	64
3.6 Summary – Theoretical Decision-Making Model	68
<b>Chapter 4: Research Design</b>	<b>71</b>
4.1 Outline	72
4.2 Phase 1a: Determine the processes oil and gas	

	companies should use to make decisions	73
4.3	Phase 1b: Identify the processes oil and gas companies say they do use to make decisions.	76
	4.3.1 The Researcher	77
	4.3.2 Interpretive Paradigms	78
	4.3.3 Strategies of Inquiry	79
	4.3.4 Collecting, Analysing, Interpreting and Evaluating the Data	81
4.4	Phase 2: Develop an oil and gas decision-making Taxonomy and determine the decision types.	81
4.5	Phase 3 – Compare and contrast theoretical and “real world” models to determine good decision-making processes.	84
4.6	Phase 4 – Develop prescriptions for good decision-making and tailoring decision-making process to decision type.	85
<b>Chapter 5: How Oil and Gas Companies Say They Make Decisions</b>		<b>87</b>
5.1	Introduction	88
5.2	Data Collection	88
	5.2.1 Participants	88
	5.2.2 Procedure	89
5.3	Data Analysis	90
	5.3.1 Roles and Responsibilities	91
	5.3.2 Decision Types	98
	5.3.3 Decision-Making Processes and Tools	101
	5.3.4 The Human Side of Decision-Making	108
	5.3.5 Learning Feedback	112
5.4	Data Interpretation and Evaluation	117
	5.4.1 Hierarchical Decision-Making in Oil and Gas Companies	117
	5.4.2 Trust Heuristic	121
5.5	Conclusions: “Real World” Oil and Gas Decision-Making Model(s)	122
	5.5.1 Individual or Core Decision-Making Process	122
	5.5.2 Hierarchical Approval Process	123
	5.5.3 Portfolio Management Processes	124
<b>Chapter 6: Taxonomy Development</b>		<b>127</b>
6.1	Introduction	128
6.2	Implementation	130
	6.2.1 Procedure	130
	6.2.2 Materials	133
	6.2.3 Participants	134
6.3	Results	135
	6.3.1 Additive Tree-Fitting	136
	6.3.2 Additive Clustering	137
6.4	Discussion	138
6.5	An Oil and Gas Decision-Making Taxonomy	143

---

6.6	Conclusions	148
<b>Chapter 7: Decision Types</b>		<b>149</b>
<b>Chapter 8: Prescriptions for Good Decision-Making</b>		<b>157</b>
8.1	Introduction	158
8.2	Hypothesis One	156
8.3	“Real World” and Theoretical Models	161
	8.3.1 Similarities Between the Models	161
	8.3.2 Differences Between the Models	162
8.4	Possible Changes	169
	8.4.1 What is Systematically Desirable? – Static (Procedural) and Dynamic (Functional) Changes	170
	8.4.2 What is Culturally Feasible – Attitudinal Changes	174
8.5	Prescriptions for Good Decision-Making	176
8.6	Summary	178
<b>Chapter 9: Processes Used in the “Real World” for Decision Types</b>		<b>179</b>
9.1	Introduction	180
9.2	Hypothesis Two	182
9.3	Case Study Analysis	184
	9.3.1 Single Process	185
	9.3.2 Differing Processes	193
	9.3.3 Polarised Processes	195
9.4	Changes in Decision Process Given Changes in Decision Taxonomy	198
	9.4.1 Changes in Complexity	198
	9.4.2 Changes in Constraints	199
	9.4.3 Changes in Ambiguity	201
	9.4.4 Changes in the Structure of the Environment of Information	203
9.5	Do Companies Actually Make Decisions the Way they Say they do?	204
9.6	Further Prescriptions for Good Decision-Making	205
9.7	Conclusions	206
<b>Chapter 10: Conclusions and Recommendations</b>		<b>209</b>
10.1	Introduction	210
10.2	Answering the Research Questions	210
10.3	Further Research	217
10.4	Conclusion	220
<b>Bibliography</b>		<b>221</b>

<b>LIST OF FIGURES</b>	<b>Page</b>
1.1 Structure of Thesis	6
2.1 Typical Utility Curve	14
2.2 A Hypothetical Value Function	19
2.3 Russo and Schoemaker's pyramid of choice approaches	27
2.4 A Decision Support Framework for Major Accident Hazard Safety	39
3.1 Three Factors Determine Decision Outcome	50
3.2 Decision-Making Process	52
3.3 Decision Analysis Process Flowchart	52
3.4 Decision Analysis Cycle	53
3.5 Four Stages of the Decision Process	53
3.6 Nutt's Discovery Process	55
3.7 Nutt's Idea Imposition Process	55
3.8 Eight Step Multiobjective Decision-Making Process	56
3.9 Multilevel Theory of Hierarchical Decision-Making	66
3.10 Theoretical Model of How Companies Should Make Decisions Under Uncertainty	70
4.1 Research Program Phases	72
4.2 Checkland's Soft Systems Methodology	74
5.1 Triangle of Decision Recommendations	118
5.2 Triangle of Decision Perspective	119
5.3 Balanced Hierarchy of Decision-Making	120
5.4 The Trust Heuristic	121
5.5 A "Real World" Oil and Gas Decision-Making Under Uncertainty Model	125
6.1 Graphical User Interface Showing Similarity Scale	132
6.2 Bayesian Information Criterion (left hand scale, solid line) and Percentage of Variance Accounted For (right hand scale, broken line) values for the similarity data using tree-fitting algorithm	136

6.3	Best tree-fitting result with 5 clusters represented by the different colours and is explained in section 6.5	137
6.4	Bayesian Information Criterion (left hand scale, solid line) and Percentage of Variance Accounted For (right hand scale, broken line) values for the similarity data using additive clustering algorithm	137
6.5	Best clustering result of 7 clusters shown on multidimensional-scaled representation	138
6.6	Percentage of Variance Accounted For (VAF) versus Precision Measure	140
6.7	Number of Clusters versus Precision Measure	140
6.8	Bayesian Information Criterion (left hand scale, solid line) and Percentage of Variance Accounted For (right hand scale, broken line) values for the similarity data using clustering algorithm	141
6.9	Optimal clustering result of 4 clusters shown on multidimensional-scaled representation	141
6.10	Oil and Gas Decision-Making Taxonomy Template	148
7.1	Decision to Develop a Discovery	150
7.2	Optimising Production Decision	151
7.3	Reserves Estimation Decision Type	152
7.4	Klein's Naturalistic Decision-Making for Emergencies	153
9.1	Tailoring Decision Process to Decision Type	183
9.2	Characterisation of Axe-Type Decision	186
9.3	Klein's Recognition-Primed Decision Model – Naturalistic Decision-Making	187
9.4	Characterisation of Funnel-Type Decision	189
9.5	Funnel-Type Decision-Making Process	189
9.6	Characterisation of Matchbox-Type Decision	190
9.7	Matchbox-Type Decision-Making Process	191
9.8	Characterisation of Shears-Type Decision	192
9.9	Shears-Type Decision-Making Process	192
9.10	“Go” / “No Go” Block Decision Process	196
9.11	Complex Block Decision Process	197

<b>LIST OF TABLES</b>	<b>Page</b>
3.1 Decision Process versus Outcome	51
3.2 Matrix of process and method (after Barker, 2001)	63
4.1 Interpretative Paradigms (after Denzin and Lincoln, 2005)	79
4.2 Advantages and Disadvantages of Structured and Semi-Structured Interviews	80
6.1 Similarity Matrix	132
6.2 Survey Participants	134
7.1 Summary of Primary Decision Types	154
8.1 Measures of “Goodness”	160
9.1 Number of Decision Types Discussed	181
10.1 Prescriptions for Good Decision-Making	216

<b>LIST OF APPENDICES</b>	<b>Page</b>
1. Papers Published during Research	A1.1
2. Outline of Semi-Structured Interview	A2.1
3. Request to Participate in Semi-Structured Interviews	A3.1
4. Transcripts of the Digitally Recorded Semi-Structured Interviews	A4.1
5. Summary Notes of the non Digitally Recorded Semi-Structured Interviews	A5.1
6. Decision Scenarios	A6.1
7. Submission for approval of the University of Adelaide’s Human Research Ethics Committee	A7.1
8. Participant Request	A8.1
9. Information Sheet	A9.1
10. Consent Form	A10.1
11a. MATLAB Data Collection Algorithms	A11a.1
11b. MATLAB Data Analysis Algorithms	A11b.1
12. Decision Process and Decision Type	A12.1



## ABSTRACT

Business under-performance in the upstream oil and gas industry, and the failure of many decisions to return anticipated results, has led to a growing interest over the past few years in understanding the impacts of current decision-making tools and processes and their relationship with decision outcomes. Improving oil and gas decision-making is thus, increasingly, seen as reliant on an understanding of what types of decisions are involved and how they actually are made in the “real world”.

There has been significant work carried out within the discipline of cognitive psychology, observing how people actually make decisions. However, little is known as to whether these general observations apply to decision-making in the upstream oil and gas industry. Nor has there been work on how the results might be used to improve decision-making in the industry.

This research is a step towards filling this gap by developing two themes – decision-making process and decision type. It distils a “real world” oil and gas decision-making model together with a theoretical decision-making model. Comparing and contrasting the two models yields several prescriptions for improved decision-making in the upstream oil and gas industry.

This research also documents the development of an oil and gas decision-making taxonomy that lays a decision space within which to judge the processes of decision-making. The taxonomy builds on established ideas in the human decision-making literature, but is itself novel, and involves four different dimensions: 1) complexity; 2) task constraint; 3) value functions; and 4) structure of the information environment.

A primary observation is that decision-making processes are tailored to the various types of decisions. It is argued that maximising the chances of a good outcome in “real world” decisions requires the implementation of such tailoring.

## Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

---

Steven I Mackie

---

Date

## Acknowledgements

Whilst the work documented in this thesis is my own – and I take full responsibility for it – it certainly did not come into being without the help and support of many others. I would, therefore, like to take the opportunity to thank those who contributed.

First, recognition needs to go to my supervisors, Prof. Steve Begg, Dr. Chris Smith and Dr. Matthew Welsh. Each contributed in their own unique way. The work crosses several faculty and school boundaries (School of Petroleum, Graduate School of Management and School of Psychology) and thus allows for marvellous opportunities – all new ideas come at the boundaries. It also requires dedicated effort from the people to break through the silos. Funding for the research comes from an Australian Research Council grant (ARC linkage LP0453894). This is financially supported by BHPBilliton and Santos. Appreciation must go to them. The grant was obtained by submission from Prof. Begg, Prof. Reidar Bratvold (University of Stavanger) and Assoc. Prof. Michael Lee (University of California – Irvine) – thanks. The research also called for volunteer participants in several rounds of interviews. In an industry that is already stretched with limited resources, the fact that these people gave their time and ideas willingly speaks volumes. Due to confidentiality it is impossible to thank them all individually, which is what I would like to do, but must settle for a general: “Thanks Guys!” I especially appreciated the candid comments and suggestions of my examiners.

Now to the motivators and finishers. My late mother always pined “one day I would like a doctor in the house.” Mum this is for you. Finally, and by far the most important, thanks must go to Violet, who not only supported me through the entire ordeal but was the greatest sounding board, editor and finisher!! She has to be the best eternal companion anyone could ask and pray for – someone of like thought and aspiration.

***Professor Higgins was wrong!***

***You have got to let a woman in your***

***life<sup>1</sup> to be successful!!***

***To the two women in my life –***

***Violet – my eternal companion***

***Norma – my mother***

---

<sup>1</sup> Taken from George Bernard Shaw's 1913 play, Pygmalion

## Presentations and Papers

The research project has generated the following presentations and papers.

### PRESENTATIONS (in reverse chronological order)

1. **Decision Type: A Key to Realizing the Potential of Decision-Making Under Uncertainty**, presented at the Australian Petroleum Production and Exploration Association annual conference, April 2007
2. **Human Decision-Making in the Upstream Oil and Gas Industry**, presented at the Annual General Meeting of the Petroleum Exploration Society of Australia (SA Branch), March 2007
3. **PhD Progress Presentation – Year End 2006 Status Report**, presented to BHPBilliton (PhD sponsors via ARC Linkage Grant), November 2006
4. **Realizing the Potential of Decision-Making Under Uncertainty**, presented at the American Association of Petroleum Geologists International Conference, November 2006
5. **An Oil and Gas Decision-Making Taxonomy**, presented at the Society of Petroleum Engineers Asia Pacific Oil and Gas Conference and Exhibition, June 2006
6. **PhD Progress Presentation – Year End 2005 Status Report**, presented to Santos (Ph.D. sponsors via ARC Linkage Grant), February 2006
7. **Would You Know A Good Decision If You Saw One?**, Presented to Santos (PhD sponsors via ARC Linkage Grant), August 2005
8. **Human Decision-Making in the Oil and Gas Industry**, presented at the Centre for Improved Business Performance, Australian School of Petroleum, University of Adelaide, March 2005
9. **Group Heuristics and Biases**, presented at the Centre for Improved Business Performance, Australian School of Petroleum, University of Adelaide, February 2005

## **PAPERS (Appendix 1)**

1. **Mackie, S.I., Welsh, M.B. and Lee, M.D.**, 2006, An Oil and Gas Decision-Making Taxonomy, SPE paper 100699.
2. **Mackie, S.I., Begg, S.H., Smith, C.S., and Welsh, M.E.**, 2007, Decision Type: A Key to Realizing the Potential of Decision-Making Under Uncertainty, *AAPEA Journal*, Volume 22, Number 1, pp 307 – 317. Won Best Paper Award.